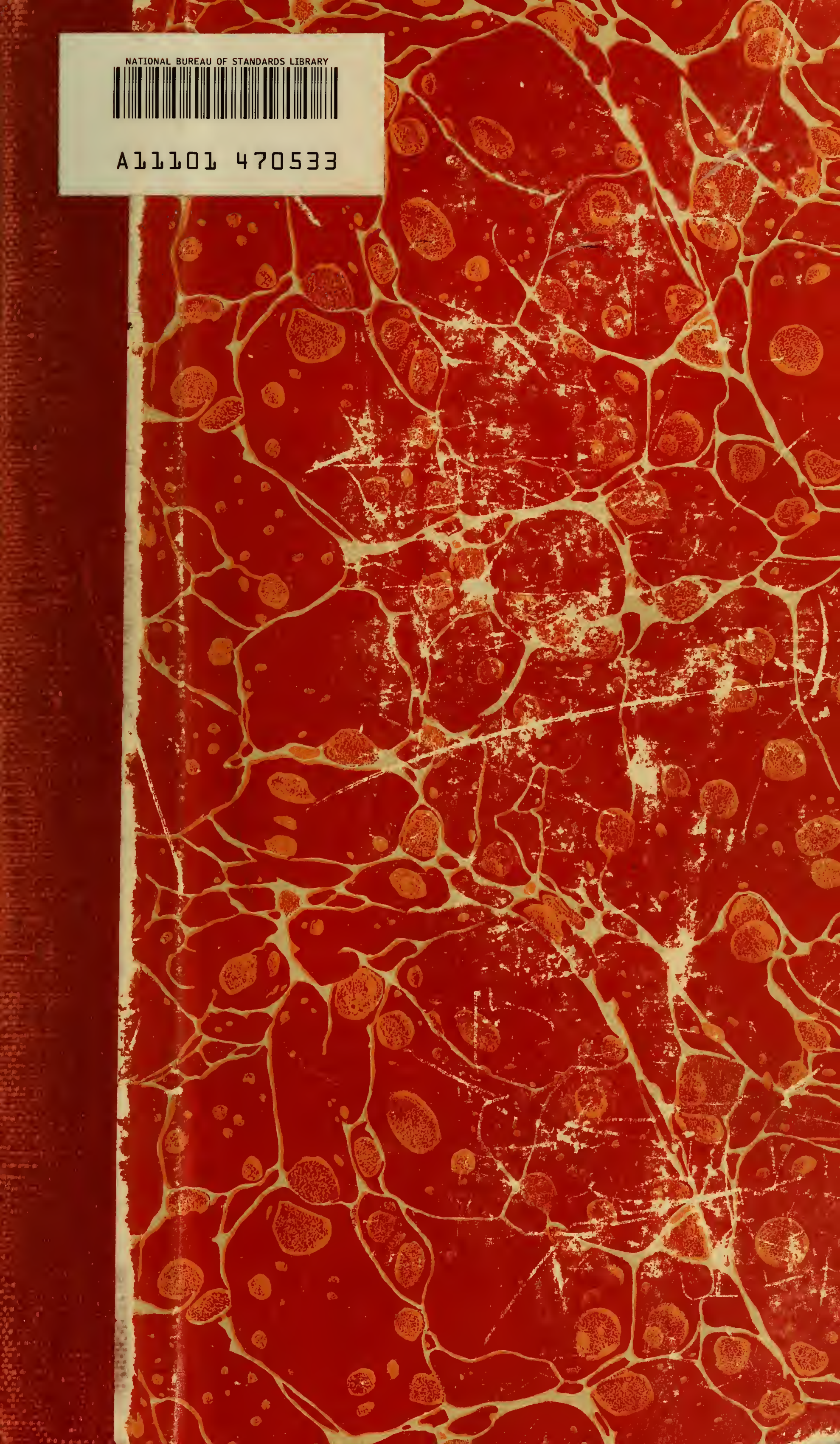
NATIONAL BUREAU OF STANDARDS LIBRARY

A11101 470533



U.S. DEPARTMENT OF COMMERCE NATIONAL BUREAU OF STANDARDS

RESEARCH PAPER RP715

Part of Journal of Research of the National Bureau of Standards, Volume 13, September 1934

CRITICAL STUDY OF THE DETERMINATION OF ETHANE BY EXPLOSION WITH OXYGEN OR AIR

By Joseph R. Branham and Martin Shepherd

ABSTRACT

This paper presents the results of a series of analyses of pure ethane by the explosion method. Explosions were made with commercial oxygen, pure oxygen, and air. The results are compared with previously reported data obtained by slow combustion. Large differences were observed between the various groups of analyses, and no group gave results corresponding to the ideal equations. These differences are partly explained by errors found and measured. In general, the explosion methods were very inaccurate, possibly far more inaccurate than is commonly suspected.

CONTENTS

		Page
I.	Introduction and summary of all observed data	377
II.	Explosion with commercial oxygen	381
III.	Explosion with pure oxygen	385
IV.	Explosion with air	386
V.	The "rapid" slow combustion of ethane	387
VI.	Significance for "exact" gas analysis. (Results of computing observed data by the conventional equations)	388

I. INTRODUCTION AND SUMMARY OF ALL OBSERVED DATA

In a previous study of the determination of ethane by the slow combustion method,[1] it was found that ethane (known to be pure) did not react in accordance with the ideal volumetric equation, $C_2H_6+3.5\ O_2 \rightarrow 2.0\ CO_2+2.5TC$, but gave instead a reaction expressed by the volumetric equation

$$C_2H_6+3.513\ O_2 \rightarrow 1.994\ CO_2+2.520\ TC,$$

where O_2, CO_2, and TC are symbols used to identify the numbers representing the relative volumes of oxygen consumed, carbon dioxide produced, and contraction, respectively, upon burning one volume of ethane. This observed equation does not agree with the ideal equation even when the latter is corrected for the deviations of ethane and carbon dioxide from ideality. Several sources of error inherent to the process were found, such as solution of ethane and carbon dioxide in the distributor connections and lubricant; and when the measured effects of these errors were taken into account, the corrected results were in only fair agreement with the observed data, which were thus partially, but not fully, explained.

---

[1] Martin Shepherd and Joseph R. Branham, *A critical study of the determination of ethane by combustion over platinum in the presence of excess oxygen.* BS J.Research 11 783(1933);RP625.

The present paper reports the results of a similar study of the determination of ethane by the explosion method. The ethane examined was from the same container as that used in obtaining the data by the slow combustion method, and was known to be pure so far as this work is concerned, since the only impurity detected (by the previously reported sensitive method) was approximately 0.01 percent of nitrogen.[2] This ethane was burned explosively with oxygen from three sources:

(1) Commercial oxygen obtained by air separation, containing 0.76 percent of nitrogen (or nitrogen + inerts).

(2) Pure oxygen, obtained electrolytically (from sodium hydroxide), from which hydrogen was removed by repeated passage over a glowing platinum spiral. In this case, it is also important to note that pure oxygen replaced the nitrogen ordinarily employed to fill the distributor and the manometer arm connected thereto. Thus any effect caused by the presence of nitrogen was eliminated.

(3) Oxygen in normal air.

The three series of analyses employing oxygen from the sources mentioned gave different results, and all these results differed from those obtained by slow combustion. The following volumetric relationships represent the averages taken from the observed data, and illustrate this divergence.

(1) Explosion with commercial oxygen:

$$C_2H_6 + 3.558\ O_2 \rightarrow 1.986\ CO_2 + 2.594\ \text{TC}.$$

(2) Explosion with pure oxygen:

$$C_2H_6 + 3.525\ O_2 \rightarrow 1.988\ CO_2 + 2.525\ \text{TC}.$$

(3) Explosion with air:

$$C_2H_6 + 3.497\ O_2 \rightarrow 1.990\ CO_2 + 2.528\ \text{TC}.$$

For comparison, the observed result for slow combustion[3] may again be given:

$$C_2H_6 + 3.513\ O_2 \rightarrow 1.994\ CO_2 + 2.520\ \text{TC}.$$

The results observed are also presented graphically (fig. 1) as percentages of ethane computed from the observed analytical data. (These results are computed from equations given in fig. 1, wherein S represents the volume of sample.) The deviations from 100 percent at once establish the relative accuracy of the various methods. The precision (i.e., reproducibility of results) of the methods is also apparent from the scattering of points. The results for the 18 analyses by slow combustion, taken from the previous report, are included for comparison. The data obtained by each of the four methods are grouped separately, and the results obtained by each method of computation are represented by a separate symbol. Where identical numerical results were obtained, they were plotted one above another on the same vertical line.

---

[2] The determination of the purity of the ethane used in the present work is given in the previous report (see footnote 1). A detailed description of the method used for this test is given in BS J.Research **12**, 185(1934); RP643.

[3] See footnote 1.

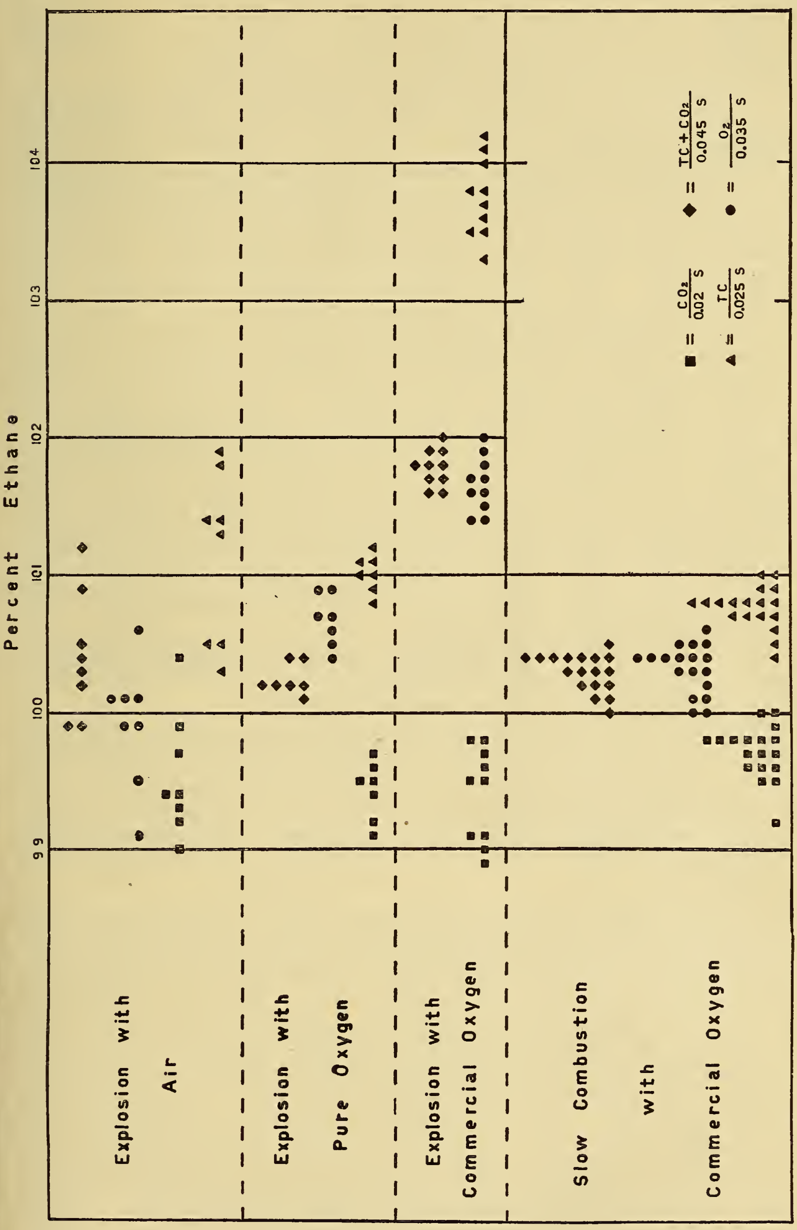


FIGURE 1.—*Results of the determination of pure ethane by explosion with commercial oxygen, pure oxygen, and air.*

Previously reported data for slow combustion are included. The commercial oxygen was obtained by air separation and contained about 0.7 percent of nitrogen. In the analyses with pure oxygen, nitrogen was eliminated from the reaction.

A brief survey of the observed results (fig. 1) and of the average volumetric equations given will at once indicate several important facts.

(1) It is apparent that the presence of small amounts of nitrogen during the explosion will greatly influence the contraction and oxygen consumed. The values in the case of explosion with commercial oxygen differ markedly from those of the other groups.

The effect of eliminating nitrogen from the explosion is strikingly illustrated by the data for explosion with pure oxygen.

(2) The amount of carbon dioxide produced exhibits the least tendency to differ between different groups; indeed, these values are in reasonable agreement.

(3) In the case of explosion with air, the averages for the oxygen consumed and carbon dioxide produced seem to indicate a satisfactory reaction, but, as will be shown later, this group afforded evidence of incomplete combustion to a much greater extent than did any of the other groups. The wide divergence of these results shows that the method is unsatisfactory as regards precision.

(4) The precision resulting from explosion with commercial oxygen is much better than that obtained by explosion with air, but the accuracy is extremely poor unless the results are corrected (as will be done in the following section of the paper). Such corrections may not always be satisfactory, and cannot be generally recommended.

(5) From the standpoint of precision, explosion with pure oxygen is apparently as satisfactory as slow combustion; the accuracy is not. However, the accuracy apparently attained with this type of explosion is comparable with that obtained by slow combustion, if ethane is computed from $TC+CO_2$ (i.e., by the formula $100\ (TC+CO_2) \div 4.5\ S$, where S is the volume of sample. The method has some merit if a rapid analysis is required.

(6) From the viewpoint of accuracy as well as precision, the slow combustion method is apparently superior; but even this method is subject to considerable error, as has been shown.

In addition to the above, it may be noted in the case of explosion with commercial oxygen or with air, nitrogen was lost in every single analysis.[4] In the case of the slow combustion, nitrogen was lost in 13 out of 18 analyses.[4] But in the case of explosion with pure oxygen, nitrogen was apparently gained in all analyses. This point is illustrated graphically in figure 2, but discussion of its probable significance will be deferred.

Having thus summarized the important facts, the balance of the paper will be devoted to discussing the observed data for each of the series of analyses, together with several interesting experimental facts which were found in the course of each series. These facts illustrate peculiarities inherent in the processes, and suggest methods of minimizing errors. At the same time, the results will be corrected for deviations of ethane and carbon dioxide from ideality, and for known errors caused by solution in rubber and lubricant. It will be shown that these corrections will not explain the observed facts, as they did to a considerable extent in the case of the slow combustion series. Other errors, some known to be present, will be discussed in order to show the various possible explanations of the observed data. While these are worth noting, the analyst will find that his real interest must center in the fact that the accuracy which can be obtained by any of these methods is very far from satisfactory, perhaps farther than is generally suspected. Thus, employing the commonly used method of computation,[5] it is possible to obtain indications of 12 to 18 percent of methane (where it is known there is no methane) and about 90 percent of ethane, for a round sum of 106 to 108 percent of sample.

---

[4] The figure shows several points on the 0 ml line. This happens simply because the data actually obtained are given to the nearest 0.02 ml.

II. EXPLOSION WITH COMMERCIAL OXYGEN

As stated before, the commercial oxygen was obtained by air separation and contained 0.76 percent of nitrogen and inerts. In addition, the distributor and the distributor arm of the manometer were filled with nitrogen at the beginning of each analysis. Thus 2 to 3 ml of nitrogen was present at the time of the explosion of the ethane-oxygen mixture, and it was expected that some of the nitrogen would react with the oxygen, which was always in excess of that required to react with the ethane.

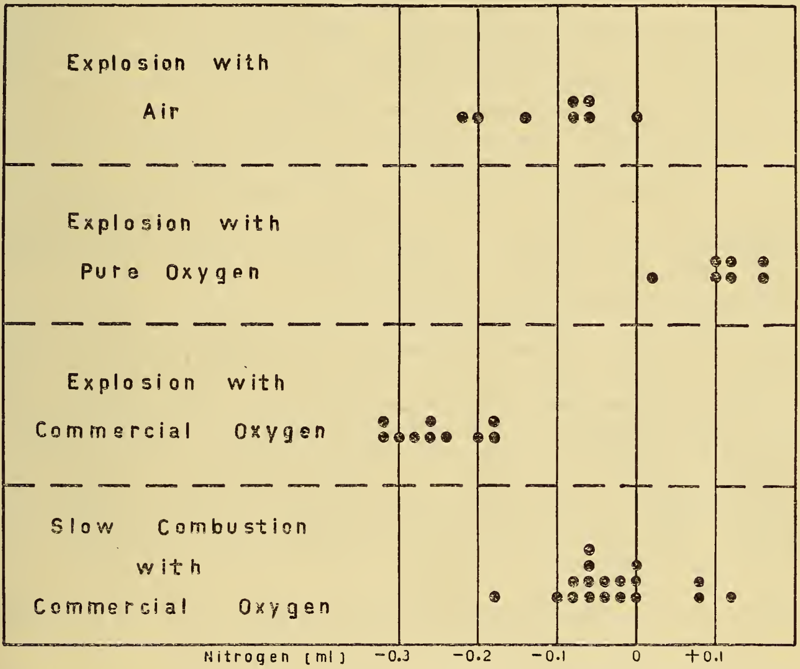


FIGURE 2.—"*Nitrogen*" *lost or gained during each analysis by the various methods.*

This "nitrogen" represents the failure to check the original amount of gas present in the distributor and manometer at the beginning of each analysis. Since there was no nitrogen in the sample of ethane, the "nitrogen" observed may represent volumetric error or gas which did not react during combustion or absorption.

The analytical procedure was simple. After filling the distributor with nitrogen at the fixed pressure of the compensator, an average of 10.6 ml of pure ethane was measured and transferred to an explosion pipette. (This pipette was constructed with very heavy walls, and with no stopcock at the bottom to restrict surges of mercury. The spark gap was arranged so that the spark might be passed at the dome or at the center of the pipette.) The sampling lines were then carefully flushed with mercury and with oxygen, following which an average of 62.8 ml of the commercial oxygen was measured and transferred to the explosion pipette. This oxygen (together with the gas in the manometer) was passed rather slowly through the distributor, so that ethane which had dissolved in the rubber and lubricant might have opportunity to be regained (at least partially) and so be carried into the explosion pipette. The gases were throughly mixed in the explosion pipette, and then ignited under slightly reduced pressure. The explosion was violent. Following the explosion, the residual gas was (1) returned to the burette where measurements were taken over a period of 10 to 15 minutes; or (2) allowed to remain in the explosion pipette for 10 minutes, with occasional stirring, before returning to the burette for final measurements. (The reason for this technique will be given in the next paragraph.) The carbon dioxide was then removed by ascarite,[6] and the excess oxygen by alkaline pyrogallol.

---

[5] Methane and ethane computed from TC and CO_2 according to the conventional equations.

The most notable feature of these analyses was the fact that after the actual explosion had taken place, a small contraction occurred over a period of about 10 minutes. Thus if the products of combustion were immediately transferred to the burette, it was possible to measure this continuing small contraction until finally the volume remained constant (within .02 ml). In this manner, several tenths of one ml would disappear between approximately the third and the tenth minute elapsing after explosion.[7]

A reasonable explanation for this observed secondary contraction appears to be the formation of oxides of nitrogen which react with water or mercury in the pipette and burette. (Solution of carbon dioxide, or thermal effects, do not satisfactorily explain this behavior.) Thus, the nitrogen which combines with excess oxygen causes an error of considerable magnitude, which is reflected in the TC and O_2 values, and does not substantially affect the CO_2, since little if any NO_2 (or N_2O_4) reaches the ascarite if the prescribed technique is followed. Experimental evidence supporting this explanation was obtained in two ways.

(1) If the residue from explosion was taken immediately into the burette, and the burette was then washed with a few ml of distilled water, a cloudy precipitate formed which, when analyzed, proved to be a mercury salt.

(2) The explosion pipette was washed with 10 ml of distilled water and 20 ml of nitrate-free sulphuric acid (95 percent), and the solution tested for nitrates by adding 0.5 ml of saturated ferrous sulphate solution. A strongly positive test for nitrates was obtained.

This explanation also agrees with the fact that nitrogen was lost in every one of the 10 analyses of this series. This loss averaged 0.25 ml with no great deviation therefrom, and is illustrated graphically in figure 2.

Determinations of carbon monoxide occurring in the products of combustion were made for several analyses of each group.[8] These determinations furnished one of two series of experimental data used to judge the completeness of combustion. For the explosions with commercial oxygen, an average of 0.03 ml of CO was found in the products of combustion, corresponding roughly to 0.3 percent of the average volume of the sample used.

---

[6] For details of this procedure for the removal of carbon dioxide, see previous report, footnote 1.

[7] This behavior was observed by the second author in 1919–21 in connection with the explosion of natural gas with oxygen. A study of the error involved in the analysis of natural gas from the Petrolia, Tex., field indicated average errors of several percent. In this work, the residual contraction measured over the first 3 minutes following the explosion was usually over 0.3 ml. (Unpublished report of the U.S. Experimental Helium Plant no. 3, by Martin Shepherd and F. W. Schraeder).

[8] Carbon monoxide was determined by the iodine pentoxide method. These determinations were made by Carroll Creitz of this laboratory.

The second experimental evidence used to judge the completeness of combustion was obtained by burning the residue from the explosion (after first removing the carbon dioxide) by passage over the heated platinum spiral of the combustion pipette. Whenever this was done a slight additional contraction was observed, and some additional carbon dioxide found. The amounts involved were small—of the order of magnitude of 0.1 to 0.3 ml for the sum of the additional $TC+CO_2$. The significance of these observations is uncertain, not only because of the small volumes involved (which would represent, of course, much smaller volumes of C_2H_6), but also because of the fact that, if unburned C_2H_6 was really found, it may have come from the rubber and lubricant of the distributor rather than from the products of explosion. Hence, this evidence tends only to throw suspicion upon the completeness of combustion, rather than to prove it quantitatively.

With these various experimental facts and the corresponding possible explanations in mind, it will be interesting to examine the observed data merely to see what might have happened to produce these results. For this purpose, only the average results will be employed. They will first be corrected for errors known to be present, and finally for errors which may or may not have been present.

Since ethane was the only combustible compound present, the amount can be computed from the observed TC, CO_2 or O_2 (or various combinations of these quantities). If the ideal volumetric relationships prevail, all methods of calculation should give an identical result; and with the ethane used, the common result would be 100 percent. In the following computations, ethane will be computed from the three relevant quantities, according to the equations:

$$(1)\quad \text{Percent } C_2H_6 = TC/2.5\ S \times 100$$

$$(2)\quad \text{Percent } C_2H_6 = CO_2/2.0\ S \times 100$$

$$(3)\quad \text{Percent } C_2H_6 = O_2/3.5\ S \times 100$$

In addition a formula which has the merit of automatically correcting for deviations of carbon dioxide from ideality, and losses of carbon dioxide by solution in rubber, lubricant and water will be occasionally included:

$$(4)\quad \text{Percent } C_2H_6 = (TC+CO_2)/4.5\ S \times 100$$

The object of the computations will be to show the effect of known errors, by correcting the observed data; and then to show how closely these corrected data may be made to agree (1) among themselves and (2) with the known purity of the sample.

The average percentages of ethane computed from the various observed data for this series of explosions are: from TC, 103.8; from CO_2, 99.3; from O_2, 101.7; (from $TC+CO_2$, 101.8).

The first corrections to be applied are (1) for the deviations of ethane and carbon dioxide from ideality, and (2) for the known losses of ethane and carbon dixoxide by solution. These corrections are made in exactly the same manner as in the previous report covering the analysis by slow combustion.[9] The only differences are (a) the factor used for deviation of carbon dioxide was slightly changed to correspond to the lower average partial pressure of this gas in the products of combustion; and (b) a smaller correction was made for losses by solution, since the procedure for explosions required less time. When these corrections are made, the percentages of ethane become: from TC, 103.0; from CO_2, 98.7; from O_2, 100.7; (from $TC + CO_2 = 101.1$). Such corrections are not sufficient to bring the various quantities into agreement with themselves or the known sample.

Next, a correction can be made for the average amount of carbon monoxide found. If this is done, the results are only slightly altered. The percentages of ethane are: from TC, 103.1; from CO_2, 98.9; from O_2, 100.8.

Following this correction, one can be made for the measured loss (0.25 ml) of nitrogen. An assumption (which seems reasonably verified by experimental evidence) must be made—i.e., that the nitrogen lost combined with oxygen to form N_2O_4, which reacted with water or mercury and disappeared from the gas phase before the absorption of carbon dixoide. Corrections made according to these assumptions change the calculated percentages of ethane to the following values: from TC, 99.9; from CO_2, 98.9; from O_2, 99.3.

It may now be interesting to make several additional assumptions regarding the possible degree of incompleteness of combustion, although little experimental evidence is at present available to support them. Aside from the determination of carbon monoxide in the products of combustion, and the doubtful evidence presented by the small secondary $TC + CO_2$ produced when the products of explosion were burned by the slow combustion method, there is some additional information which tends to throw suspicion on the completeness of combustion. This information did not appear until the series of explosions with pure oxygen, and it is therefore necessary at this point to anticipate. Referring to figure 2, which illustrates graphically the amount of gas left at the end of each analysis (which is ordinarily called nitrogen or inert, but which really represents the amount by which the analysis failed to reach the original balanced condition of the nitrogen-filled distributor system), it will be seen that "nitrogen" was lost in the great majority of cases, but was invariably gained in the series of explosions with pure oxygen. Since there was no measurable amount of nitrogen in the sample nor in the oxygen, this apparent gain of nitrogen must have been caused by (1) leakage from the outside, (2) solution of nitrogen (from the outside air) in the rubber connections and subsequent diffusion through the tubing, (3) the incomplete absorption of carbon dioxide or oxygen, (4) nitrogen given off from the reagents used to absorb these two gases, or (5) the actual presence of a portion of the original sample in some form or forms of incomplete combustion. Examining the likelihood of these possibilities in the order given: (1) Freedom from actual leakage was insured by repeated tests; (2) the time required for an analysis, together with the known permeability of rubber to nitrogen, throws doubt upon the possibility of gaining 0.1 ml of nitrogen through the rubber, although this is not altogether impossible; (3) repeated tests have established the completeness of absorption with the technique employed; (4) the reagents used were in substantial equilibrium with nitrogen at the beginning of the analyses, with no great changes in pressure or temperature to alter this condition. This indicates that there might have been some ethane not completely burned at the end of the analyses.

---

[9] See footnote 1.

If we assume this to be so, there are two corrections to be applied in consequence. The first of these follows from the fact that the measured nitrogen lost during the explosions with commercial oxygen is in all probability too low by the amount of the "nitrogen" gained during the explosions with pure oxygen. The second correction comes from the fact that apparently 0.1 ml of C_2H_6 did not completely burn. Since only 0.03 ml of carbon monoxide appeared in the products of combustion, it does not seem entirely unreasonable to suppose that the greater portion of the remainder still existed as ethane. (This, of course, is not necessarily true. But if other intermediate products are assumed, the corrections become hopeless, and in order to make any at all, the above assumption must be accepted.) Making these two corrections, the results (percentages of ethane) become: From TC, 99.8; CO_2, 99.5; O_2, 99.6.

Another viewpoint of the subject of incompleteness of combustion is afforded by comparing the carbon dioxide produced in each group of analyses. It will be seen (fig. 1) that these values are in fairly good agreement in every case, and apparently do not show the divergence exhibited by the contraction and oxygen consumed. It is somewhat gratifying to observe that if the carbon dioxide produced is taken as the measure of the completeness of combustion, and the data are corrected on this basis (including as before a correction for the additional nitrogen burned), the results are in reasonable agreement with those previously obtained on the basis of "nitrogen" gained. The percentages of ethane are: From TC, 99.7; from CO_2, 100.0 (by definition); from O_2, 99.8.

However, too much significance should not be accorded the assumption that the carbon dioxide correctly measures the completeness of combustion, especially in view of the fact that the carbon dioxide did not indicate the relative incompleteness of the explosions with air.

While these conjectures are somewhat interesting, the analyst should not lose sight of the really significant fact that the accuracy is far from satisfactory whatever the nature of the errors may be.

III. EXPLOSION WITH PURE OXYGEN

This group of analyses present a relatively simple picture, devoid of many of the complications encountered in the preceding group. The analysis of the data is correspondingly straightforward.

The analytical procedure was essentially the same as that used for the explosions with commercial oxygen, except that pure oxygen, instead of nitrogen, was used to fill the distributor (and the arm of the manometer attached thereto) at the beginning of each analysis. Thus nitrogen was eliminated from the reaction. This technique was made possible by the use of the calibrated distributor and manometer previously described.[10]

---

[10] For a detailed description of the use of the calibrated distributor, consult BS J. Research 6, 121(1931); RP266.

The result of eliminating nitrogen is shown by the sharp change in the values calculated from TC and O_2 values (see fig. 1). Indeed, these values are shifted to agree substantially with those obtained by the slow combustion method. It is worthy of note that the continued contraction after explosion, observed when commercial oxygen was used, was not detected in the present series.

The average observed data, calculated as percentages of ethane, give the following results: From TC, 101.0; from CO_2, 99.4; from O_2, 100.7.

When these data are corrected (in the same manner as before) for the deviations of ethane and carbon dioxide from ideality, and for the known losses of ethane and carbon dioxide by solution, the results are: from TC, 100.2; from CO_2, 98.8; from O_2, 99.8.

These results, corrected in turn for the measured carbon monoxide found in the products of combustion, become: from TC, 100.3; from CO_2, 99.0; from O_2, 99.9.

If it is now assumed that the measured gain of nitrogen represents a corresponding amount of unburned sample which exists as ethane, the corrected data become: from TC, 101.1; from CO_2, 99.7; from O_2, 100.6.

Similarly, if the carbon dioxide produced is accepted as a measure of the completeness of combustion, the corrected data become: from TC, 101.4; from CO_2, 100.0 (by definition); from O_2, 100.9.

Since no nitrogen was present to react with oxygen, with secondary reactions of these oxides with mercury or water, no further corrections need be made.

IV. EXPLOSION WITH AIR

The precision of this series of analyses was discouraging. Apparently the explosions were "not sure of themselves", and were not quantitatively reproducible. The amounts of carbon monoxide found in the products of combustion varied from 0.02 to 0.15 ml, which is additional evidence of the haphazard behavior of such explosions. The amount of sample used was necessarily small (about 5 ml), and the effect of errors of measurement was correspondingly large. Since the method was found so unsatisfactory with regard to precision, it does not seem worth while to discuss any detailed analysis of the errors involved in this case.

However, the results of applying corrections to this group of data are given in figure 3, which affords a graphical representation of the average observed and corrected data for all of the groups of analyses, including the previously reported data for slow combustion. In this figure, the corrections are numbered as follows:

1—Correction for the deviation of ethane and carbon dioxide from ideality.
2—Correction for the loss of ethane and carbon dioxide by solution in the distributor and buret.
3—Correction for carbon monoxide in the products of combustion.
4—Correction for the loss of nitrogen by oxidation.
5—Correction for the additional loss of nitrogen and for the unburned sample, assuming the gain of nitrogen observed during explosions with pure oxygen to be a measure of unburned sample.

6—Correction for unburned sample, assuming CO_2 to be a correct measure of sample burned. (Percentage of ethane calculated from $CO_2=100$ by definition. This should be kept in mind when referring to the figure.)

V. THE "RAPID" SLOW COMBUSTION OF ETHANE

It is worth while noting that a period of 2 to 3 minutes is usually specified in the literature as representing the normal duration of a slow combustion. In the previous report [11] it was stated that a much longer period was usually required, in order to insure the presence of an excess of oxygen by diffusion around the platinum spiral; and that 30 minutes was usually required to burn ethane satisfactorily.

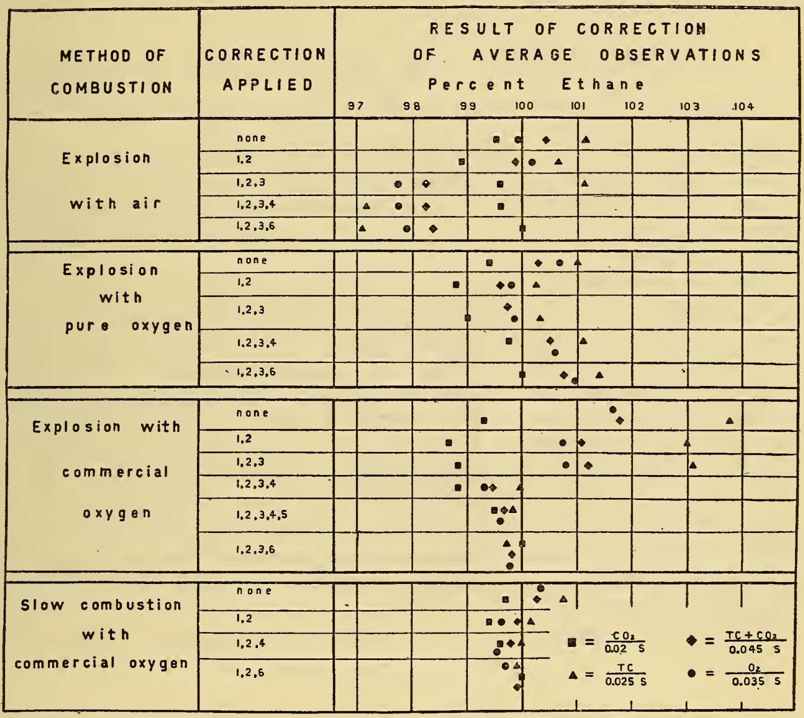


Figure 3.—*Analysis of pure ethane by the various methods, reported as the average value obtained for each series, and corrected for both known and assumed errors.*

When a slow combustion is forced to take place within the short period generally prescribed, the reaction does not occur as a true surface conbustion, but instead proceeds as a series of explosions of varying magnitude. Such an analysis might, therefore, be expected to give results intermediate between those obtained by a true slow combustion and an actual explosion.

In order to ascertain whether the "rapid" slow combustion would more nearly approximate the reaction obtained by slow combustion or by explosion (and, at the same time, in the effort to determine the practicability of the conventional procedure), several attempts were made to burn ethane by slow combustion within the allotted 2 to 3 minutes. The most successful of these attempts, from the viewpoint of speed, was accomplished in 4 minutes 25 seconds; while others were somewhat more prolonged (8 minutes). The behavior of the reaction provided a considerable amount of stimulation to the analyst, since at no time was it entirely certain that disaster would be avoided. As was expected, the general tendency was for these combustions to yield results near those found by employing actual explosion—the more rapid the slow combustion, the nearer the answer obtained by direct explosion.

---

[11] See footnote 1.

VI. SIGNIFICANCE FOR "EXACT" GAS ANALYSIS

(Results of Computing Observed Data by the Conventional Equations)

The analyst will be primarily concerned with the accuracy (as well as the precision) which he may expect from the various methods of explosion herein described. For this purpose, a few computations, based upon the observed data, will give a general idea of what may be encountered.

From the practical viewpoint, it will be necessary to suppose that the identity of the sample is not known. This represents the normal case. Thus, such a sample would usually be submitted as an unknown or, at best, as a sample of ethane of unknown purity. The analysis would be expected to disclose the possible presence of other gases. Under these conditions, the analytical data would be computed as though two hydrocarbons were present, as representing the best that could be done under the circumstances. For this purpose, the two hydrocarbons might be computed from any combination of the amounts found for TC, CO_2, and O_2; but for the present purpose, it will be sufficient to make these computations only from TC and CO_2, since this represents the normal procedure employed in by far the majority of cases.

This has been done, and the results are tabulated on page 389.

ANALYSIS OF PURE ETHANE

The Observed Data Computed as Percentages of Methane and Ethane from the Contraction and Carbon Dioxide Produced

These results are the ones that would have been obtained by an analyst using the conventional procedures for so-called "exact" gas analysis.

Method		Percentage of methane	Percentage of ethane
Explosion with commercial oxygen.	Range	17.7 12.3	90.0 93.7
	Average of 10 analyses.	14.9	91.9
Explosion with pure oxygen.	Range	6.6 4.3	95.8 97.5
	Average of 8 analyses.	5.4	96.6
Explosion with air	Range	7.7 2.2	95.2 98.9
	Average of 7 analyses.	6.0	96.8

WASHINGTON, June 26, 1934.